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The Polar Ice Prediction System 2.0 (PIPS 2.0) is a coupled ice-ocean model developed by the Naval Research Laboratory for the prediction of ice thickness, ice drift and ice concentration. The model has been run operationally by the U.S. Navy at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) since the mid-1990's and produces a 120-hour forecast of ice conditions in the Arctic and its marginal seas. PIPS 2.0 is driven by the atmospheric forecast fields from the Navy Operational Global Atmospheric Prediction System (NOGAPS). In an operational mode, PIPS 2.0 assimilates SSMI derived ice concentration each day. In a research mode, the SSMI ice concentration data is not assimilated, rather it is used for model metrics (validation). PIPS 2.0 results are presented as a time series for the period 1992-2000. Model results are correlated to the atmospheric forcing and evaluated against SSMI ice coverage data. In addition, the atmospheric forcing is evaluated against Sheba observations taken in 1997-1998. Biases in the model derived ice fields directly related to biases in the atmospheric forcing fields.

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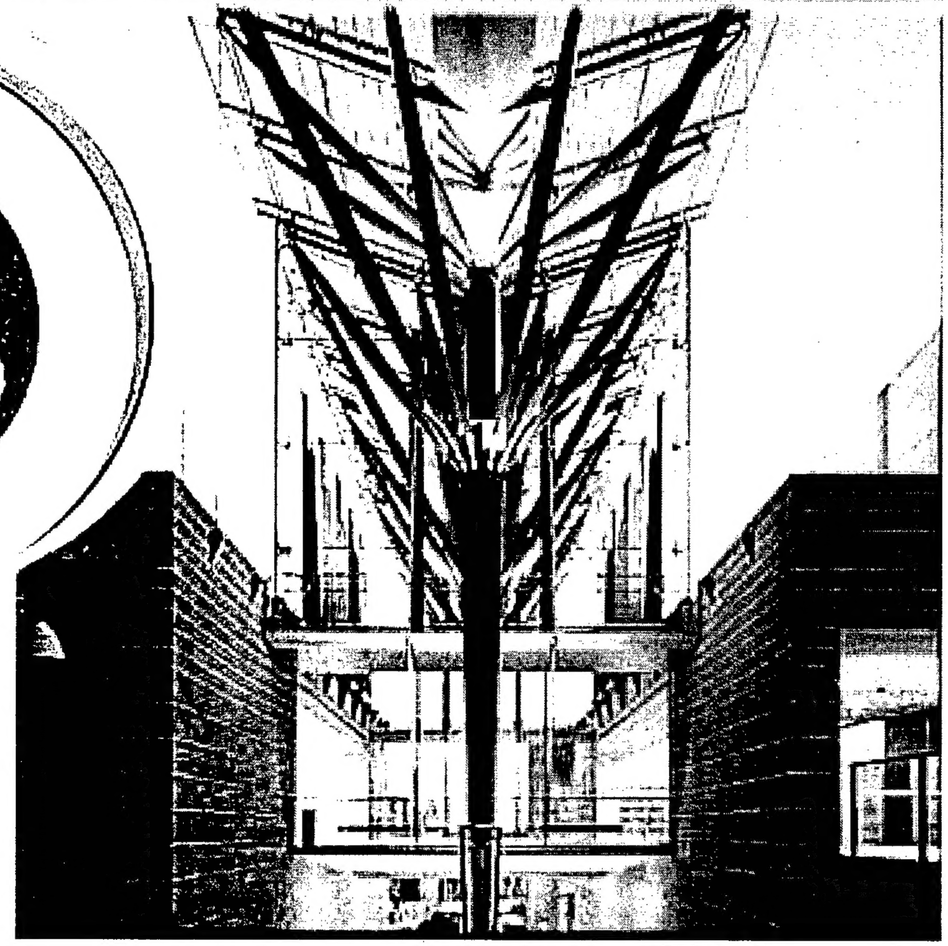

# An Evaluation of the PIPS 2.0 Ice Cover versus SSMI Ice Concentration from 1992-2000

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**Abstract- The Polar Ice Prediction System 2.0 (PIPS 2.0) is a coupled ice-ocean model developed by the Naval Research Laboratory for the prediction of ice thickness, ice drift and ice concentration. The model has been run operationally by the U.S. Navy at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) since the mid-1990's and produces a 120-hour forecast of ice conditions in the Arctic and its marginal seas. PIPS 2.0 is driven by the atmospheric forecast fields from the Navy Operational Global Atmospheric Prediction System (NOGAPS). In an operational mode, PIPS 2.0 assimilates SSMI derived ice concentration each day. In a research mode, the SSMI ice concentration data is not assimilated, rather it is used for model metrics (validation). PIPS 2.0 results are presented as a time series for the period 1992-2000. Model results are correlated to the atmospheric forcing and evaluated against SSMI ice coverage data. In addition, the atmospheric forcing is evaluated against Sheba observations taken in 1997-1998. Biases in the model-derived ice fields directly related to biases in the atmospheric forcing fields.**

## INTRODUCTION

Since the late 1980's, Arctic ice forecasting systems developed by the Naval Research Laboratory have been running operationally at the Navy's Fleet Numerical Meteorology and Oceanography Center. The first of these forecast systems, the Polar Ice Prediction System (PIPS) began operational forecasting in 1987 over a region that included the central Arctic, the Barents and the Greenland Seas. This system consisted of the Hibler ice model driven by ocean climatological currents and heat fluxes and the Navy Operational Global Atmospheric Prediction System (NOGAPS) winds and heat fluxes. The grid resolution of this system was 127 km and it was run each day generating a 120-hour forecast of ice thickness, ice drift and ice coverage (concentration). In June 1989, a higher resolution version of PIPS adapted to the Barents Sea began operational forecasting. The Regional Polar Ice Prediction System-Barents Sea (RPIPS-B) covered the Barents Sea and the western Kara Sea with a grid resolution of 25 km. In October 1991, a similar regional system for the Greenland Sea (RPIPS-G), using 20 km resolution, was made operational. However, it became obvious that more accurate forecasts required improved temporal variability in the oceanic forcing fields and improved spatial variability everywhere in the Arctic. To meet this need, the Naval Research Laboratory developed PIPS 2.0, a coupled ice-ocean system covering most of the ice-covered regions of the Northern Hemisphere. This ice-ocean model uses a horizontal resolution of 0.25 degrees and 15 vertical levels to define the ocean. Similar to the other forecast systems, PIPS 2.0 generates forecasts of ice thickness, drift and concentration.

A key to the accuracy of these forecasts is the accuracy of the forcing fields that drive the ice-ocean model. Validation of the atmospheric forcing is difficult do to considering the limited number of observations, particularly those relating to atmospheric heat fluxes. The SHEBA data set is an example of recent observations of atmospheric fluxes that may be used for model evaluation. In addition, the "accuracy" of the atmospheric forcing may be indirectly evaluated by comparing the ice-ocean model results to observations of ice extent and thickness where possible. Temporal and spatial variability in these fields will be largely due to the variability of the atmospheric forcing. As such, NRL has conducted a series of experiments using the "research" version of the PIPS 2.0 model driven by 9 years of NOGAPS forcing (1992-2000). Results from the research version are not modified by the assimilation of any observations. Therefore the variability of the modeled results will reflect the atmospheric forcing as well as the ice-ocean model parameterizations only.

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The following information is presented in this paper: 1) model description, 2) model simulation and results, and 3) summary.

## PIPS 2.0 MODEL DESCRIPTION

The PIPS 2.0 coupled ice-ocean model consists of the Hibler ice model [1] coupled to the Bryan and Cox ocean model [2]. The ice model was rewritten in spherical coordinates to be consistent with the Cox ocean model and to define a more realistic grid at the lower latitudes included in the model domain [3]. The domain extends from the pole to approximately 30° N latitude and includes the marginal seas of the Pacific, the Sea of Okhotsk, the Japan/East Sea and the Yellow Sea and the marginal seas of the north Atlantic, the Labrador Sea and the Gulf of St. Lawrence. Fig. 1 shows the model grid and the domain covered by PIPS 2.0.

The ice model uses a time step of 2 hours while the ocean model uses a time step of 0.5/0.05 hours for the temperature and salinity/velocity equations. For both the ice and ocean models, the lateral boundaries are defined as solid walls and placed far enough away from any sea-ice covered regions to avoid possible contamination of any forecast regions of interest.

The ocean model temperature and salinity fields are loosely constrained to the Levitus climatological data set. The bathymetry used by the ocean model is derived from the Navy Digital Bathymetry Data Base 5' X 5' (DBDB5). These data were interpolated to the PIPS 2.0 grid using a cubic spline function that was integrated and averaged over nine adjacent grid squares.

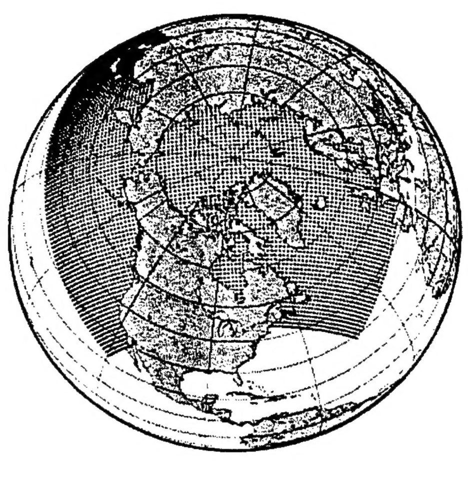

Fig. 1. PIPS 2.0 model domain and grid.

The ice and ocean models are coupled in the following manner: the ocean model passes currents, salinity and heat fluxes (temperatures) to the ice model while the ice model passes surface stresses as well as salinity and temperature changes due to the growth and decay of sea ice. Direct interaction between the ice and ocean models occurs in the first level of the ocean. This level is 30 m deep and represents the ocean's mixed layer.

The NOGAPS fields used to drive the ice-ocean model are: surface air temperature, surface pressure, surface vapor pressure, net shortwave radiation, and downwelling longwave radiation. The surface air temperature, in conjunction with the ice temperature and geostrophic winds, is used to calculate the sensible heat flux. The surface vapor pressure and the surface air pressure are used to calculate specific humidity that, in conjunction with the geostrophic winds, is used to calculate the latent heat flux.

Model output fields consist of ice thickness, ice concentration and ice drift. In addition, ocean temperature and salinity fields are also available as output.

## MODEL SIMULATION AND RESULTS

A 9-year simulation of the PIPS 2.0 ice-ocean model was generated using the 6-hourly forcing fields from the NOGAPS model for the years 1992-2000. Output from the model was viewed in two different ways. Horizontal "snapshots" of model results were used to gain a general concept of the ice coverage while time series plots of results at specific locations demonstrated the temporal variability of the modeled ice fields.

Fig. 2 is a time series of NOGAPS forcing fields from a location in the Central Arctic (~89° N, 90° W). The time series extends from 1992-2000. Note that the winter air temperatures from the fall of 1993 through the winter of 1998 were considerably warmer (10° – 15° C) than temperatures from the fall of 1998-2000. These warm winter temperatures were responsible for a reduction in winter ice growth and overall ice thickness as shown in Fig. 3. Winter ice growth increased in the

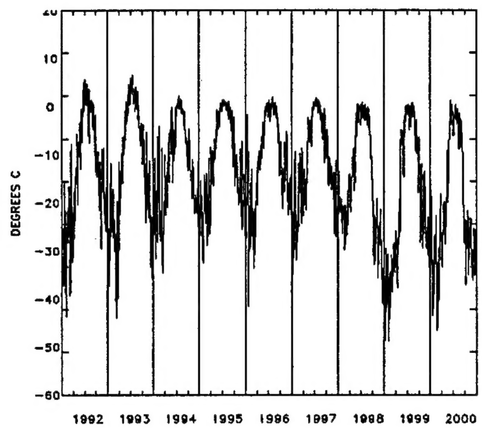


Fig. 2. Central Arctic NOGAPS surface air temperature from 1992-2000

fall of 1998 and continued through the winter of 2000. The ice concentration for this location follows a similar temporal trend with the lowest concentration values appearing in the summer of 1997 and then a increase in coverage in the summer of 1999 and 2000.

A comparison of the surface air temperature data from the SHEBA experiment and the surface air temperatures from the NOGAPS model was performed. The comparison showed that for the winter of 1997-1998, the atmospheric forcing had a warm bias of approximately $9^0$ C. If this warm bias is indicative of a similar warm bias in the NOGAPS fields in the previous 3-4 years, then the averaged modeled ice thickness during those years could be biased too thin by as much as 1m.

Ice extent in the Arctic basin during this 9-year period indicated that the summer of 1995 was the most ice free of this 9-year period with the entire

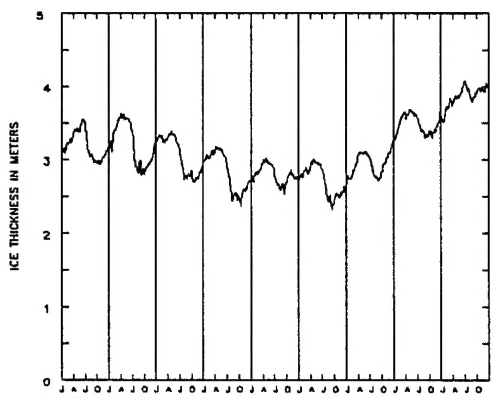


Fig. 3. PIPS 2.0 Central Arctic Ice thickness from 1992-2000.

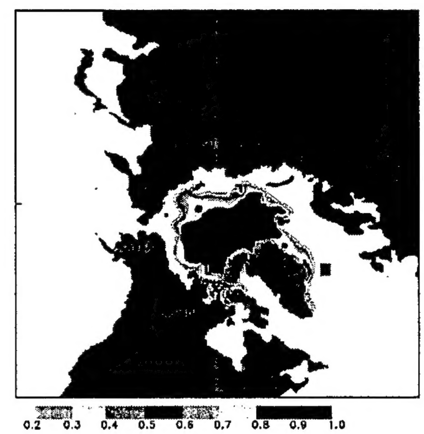


Fig. 4. PIPS 2.0 ice concentration in percent for September, 1995.

Russian coast ice free as shown in Fig. 4. The Russian coast was also nearly ice free in the summer of 1997. These trends are in good agreement with the ice coverage show by Special Scanning Microwave Imager (SSMI) data available for viewing at the following website:

http://polar.wwb.noaa.gov/seaice/Historical.html

## Summary

The PIPS 2.0 model, driven by 6-hourly forcing from the Navy atmospheric forecast model, NOGAPS, shows tendencies for a progressive thinning of sea ice from 1993-1998 and then an increase in ice thickness from late 1998 through 2000. These trends correlate closely to trends in the winter time surface air temperatures produced by NOGAPS. These tendencies also produce summer sea ice extent that shows good qualitative agreement with SSMI observations. A comparison of NOGAPS air temperatures to the SHEBA observations of air temperature indicates that the NOGAPS temperatures have a large warm bias in the winter, at least during the SHEBA year. This could imply that although trends in ice extent agree with observations, the mean ice thickness of the PIPS 2.0 could be biased thin by as much as a meter of ice thickness.

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